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THE TREATMENT OF THE PROBLEM "THE SCIENTIFIC BASES OF  
STRENGTH AND PLASTICITY" BY THE INSTITUTES OF THE ACADEMY  
OF SCIENCES UKSSR IN 1958

- USSR -

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THE TREATMENT OF THE PROBLEM "THE SCIENTIFIC BASES OF  
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[This is a translation of an article written by V.  
F. Yatsenko in Prikladna Mekhanika (Applied Mechanics), Vol  
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The activities of the institutes of the AS UkSSR  
[Academy of Sciences Ukrainian SSR] in 1958 followed the  
same three principal trends as in the preceding year 1957.\*

The research done under the heading "Static and Quasi-  
static Strength and Placticity" pertained to the development  
of the general theory of the placticity of metals, alloys,  
heat-resistant and other structural materials under complex  
loads, and the development of criteria for disruption; con-  
siderable attention was given to the elaboration of methods  
for the computation and experimental investigation of plas-  
tic flow and of short-term and long-term strength under var-  
ious temperatures; also worked on were effective methods of  
solving the spatial problems of the theory of electicity and  
placticity, and the questions of the statistical strength of  
thin-walled structures.

The research done under the heading "Strength Under  
Vibrations and Variable Loads" involved studies of the os-  
cillations of elastic systems and their critical state and  
studies of the fatigue of materials and strength of struc-  
tures under variable stresses.

The research done under the heading "Strength Under  
Impact Loads" involved studies of the effect of impact loads  
on bodies for the purpose of developing the methods of com-  
puting the response of elements of machines and structures  
to the action of dynamic loads.

All the conducted researches pertained to the engin-  
eering and physicomathematical aspects of the problem of the

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\*Of. "On the Development of the Problem of the 'Scientific  
Foundations of Strength and Placticity' by Institutes of the  
Academy of Sciences Ukrainian SSR in 1957," "Prikladna Mek-  
hanika," Vol IV, No 3, 1958

strength, plasticity and elasticity of solid bodies.\*

The principal results of the researches conducted in 1958 are as follows.\*\*

In the Field of the Development of the General Theory of the Plasticity of Metals, Alloys, and Heat-Resistant and Other Structural Materials Under Complex Loads, and the Development of Criteria for Disruption. The plastic flow of die-stamp steel under the conditions of stressed state of bulk in the temperature range of 20 to 600°C was investigated for the purpose of selecting the optimal composition of steel for die stamps with a high durability (Institute of Structural Mechanics Academy of Sciences UkSSR -- under the direction of Corresponding Member of the AS UkSSR B. D. Grozin).

A new method of research was developed: the micro-needle technique of investigating the properties of the surface layer of a material, yielding a diagram with the coordinates of the intensity and depth of penetration. Also, an installation for conducting such research was designed (Institute of Structural Mechanics AS UkSSR, under the direction of Dr. Eng. Sci. S. V. Malashenko).

During investigations of the carrying strength of disks executed of brittle materials (cast iron, "orgsklo" [organic glass?]) it was established that the criterion of carrying strength of such disks should be regarded as one constituted by the attainment by maximal stresses of the values equal to the temporary tensile strength of the corresponding materials (Institute of Powder Metallurgy and Special Alloys, under the direction of Corresponding Member of the AS UkSSR G. S. Pisarenko).

2. In the Field of the Development of Methods of the Computation and Experimental Study of Plastic Flow and of Short-term and Long-term Strength Under Various Temperatures. One subject of the related research was the role of the factor of scale in the compression of wood-laminated plastics. This revealed a comparatively small influence of irregularities of the material and a notable influence of the rate of

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\*Cf. "Problems of Soviet Science," "Scientific Foundations of Strength and Plasticity," Academy of Sciences USSR Press, 1958

\*\*The principal results of these activities are elucidated in the materials presented by the heads of the teams concerned with individual trends in the problem of strength and plasticity, and examined by the Commission on this problem.

stress growth on the ultimate compressive strength.

Other investigations pertained to the long-term strength of the EI 437Ye heat-resistant alloy the specimens of which, with and without circular notches, were exposed for 600 hours to a temperature of 830°C. It was established that the ultimate long-term strength of the notched specimens, in which the concentration of stresses is better, is higher than that of the unnotched, level ones. Also established was the ultimate long-term strength of a lap-type joint between a [turbine] blade of ZhS-6K alloy and a disk of EK 637 B alloy, all of actual design and size. The disruption in such cases was determined from the appearance of the teeth on the disk (Institute of Powder Metallurgy and Special Alloys, Academy of Sciences UkSSR, in cooperation with Kiev Polytechnical Institute, under the direction of Corresponding Member of the Academy of Sciences UkSSR G. S. Pisarenko).

The effect of the technology of the working of carbide chrome materials on their short-term strength at a temperature of 950°C was investigated. It was established that this class of materials is sensitive to surface damages caused by machining. For instance, the ultimate bending strength of ground specimens proved to be 40 percent lower than that of the nonmachined specimens and specimens worked by the electro-erosive method. It was established also that the ultimate tensile strength of the same powdered-metal carbide chrome compositions is 30-40 percent lower than their ultimate bending strength (Institute of Powder Metallurgy and Special Alloys Academy of Sciences UkSSR, under the direction of Corresponding Member of the Academy of Sciences UkSSR G. S. Pisarenko).

An installation was devised for investigating the modulus of elasticity of high temperatures (Institute of Powder Metallurgy and Special Alloys Academy of Sciences UkSSR, under the direction of Corresponding Member of the Academy G. S. Pisarenko).

Experimental studies of the static strength of welded joints at low temperatures (to -60°C) were conducted for the purpose of determining the most rational forms of connections joining elements of a tube cross section (Institute of Electric Welding AS UkSSR imeni E. O. Paton, under the direction of Candidate of Engineering Sciences V. V. Shevern'ytsky).

3. In the Field of the Development of Methods of Solving the Spatial Problems of the Theory of Elasticity and Plasticity. In connection with the values of thermal stresses in the shells of high-pressure boilers, research was extended to the nonstationary temperature field and to the thermal stresses that it causes in a non-uniformly heated hollow

cylinder, in the axial direction; also the studies pertained to the effect of temperature-caused changes in the modulus of elasticity on the distribution of thermal stresses in symmetrically heated hollow cylinders (steam locomotives); also investigated was the elastic-plastic state of thick-walled steam locomotives that are non-uniformly heated; the criterion of thin-walledness of the shell was established from the standpoint of heat conduction (Institute of Machine Science and Automation AS UkSSR, under the direction of Dr. Phys.-Math. Sci. M. Ya. Leonov).

The network method was used to solve the problem of heat stresses in a bi-connected planar massif at a given temperature field; also studied was the mixed problem of the wall stresses of a triangle-shaped dam on a rock foundation, as formed by various mutual ratios of the rigidities of the foundation and body of the dam. The results of this research were applied to investigating the stressed state of the front abutment of the Dneprodzerzhinsk Hydroelectric Power Station and the slant of the deep depression which it forms by its weight (Institute of Structural Mechanics AS UkSSR, under the direction of Dr. Eng. Sci. P. M. Varvak).

An engineering method (network method) has been developed for determining thermal stresses for a planar body of arbitrary shape at an arbitrary distribution of temperature gradients, and a study was made of the stressed state of an elastic body which was loaded while continually changing its configuration, e. g., an infinite wedge built under the conditions of a gravitational field, a torus whose wall thickness increases with increasing inner pressure, etc. (Institute of Hydrology and Hydraulic Engineering AS UkSSR, under the direction of Corresponding Member of the AkSSR B. A. Pyshkin).

4. In the Field of the Static Strength of Thin-Walled Structures. In connection with studies of the stressed state of elements of gas-turbine installations, investigation was extended to a problem of nonsymmetrical strain of round plates of varying thickness in a spatial temperature field; methods were worked out for solving the problem of heat conduction at a temperature field varying in size and in radius; a method was developed for computing, in accordance with the conditions of performance of the centrifugal blowers of turbine installations, the non-uniformly heated slanting shell, which is reinforced with ribs, is of varying thickness, and rotates at a high speed; an asymptotic method was developed for computing the conic shells with linearly varying thickness in accordance with the performance of machine parts (foundations of gas turbine, separator

rotors, etc.); a solution was found for the problem of the asymmetrical bending of a conic-profile disk in the field of the forces which act in its central area; a method was developed and realized for measuring the strain in such parts of turbo-machines as the head of the centrifugal blower, etc., which rotate at a high speed (Institute of Structural Mechanics, AS UkSSR, under the direction of Corresponding Member of the AS UkSSR A. D. Kovalenko).

In connection with the designing of the blades of hydraulic turbines, a new method was developed for computing the bending of bracket plates of varying rigidity, on utilizing integral equations; programs were compiled and materialized for computing the sector plates of varying thickness that are fastened to the internal side, by the method of integral equations and by Ritz's method on a high-speed electronic calculating machine (Laboratory of Hydraulic Machines AS UkSSR, under the direction of Corresponding Member of the AS UkSSR A. P. Filippov).

Also developed was the method of finite differences proposed in 1957 for integrating the solving equation of the toroidal shell; a method for computing designs of the type of the spiral chambers of hydraulic turbines was developed; a program was compiled and materialized for computing the toroidal shell by the method of finite differences on a high-speed electronic calculating machine; this machine was also used for executing computations to determine a number of parameters of the toroidal shell (Laboratory of Hydraulic Machines AS UkSSR, under the direction of Corresponding Member of the AS UkSSR A. P. Filippov).

Effective methods were proposed for the summation of series in accordance with the problems of the theory of plates and shells; a method was developed for computing elliptical shells by means of special functions (Institute of Structural Mechanics AS UkSSR, under the direction of Academician of the AS UkSSR G. M. Savin).

On the basis of integral equations a solution was found for the planar problem of the theory of elasticity for the multi-connected areas with cyclical symmetry; the theory of the bending of designwise orthotropic rotary shells was developed; and the basic solving of equations of nonsymmetrical strain were composed on taking into account a number of essential factors, e. g., shear strain, etc. (Institute of Structural Mechanics AS UkSSR, under the direction of Dr. Eng. Sci. D. V. Vaynberg).

On the basis of the energetic principle a method was developed for determining the critical stresses for circular shells with discrete rigid ribs (Institute of Structural

Mechanics AS UkSSR, under the direction of Academician of the AS UkSSR M. V. Kornoukhov).

A solution was found for the problem of the stressed state of a compressed circular cylindrical shell with large rectangular notches, and for the problem of the effect of the concentration of forces and moments on the edges of the shell as well (Institute of Structural Mechanics AS UkSSR, under the direction of Academician of the AS UkSSR M. V. Kornoukhov).

The cycle of investigations of the theory of the stresses of thin-walled rods beyond the elastic limit was developed, and these investigations then served as the basis for developing an engineering method of computing thin-walled steel structures beyond the limit state. The results of this research were published in a monograph by O. I. Strel'byts'kaya "Study of the Strength of Thin-Walled Rods Beyond the Elastic Limit," AS UkSSR Press, 1958.

5. In the Field of Studies of the Oscillations of Elastic Systems and Their Critical State. The effect of single-gap packings of pumps on the critical RPM of the rotor was investigated. It was established that a couple of such packings considerably increases the magnitude of the critical RPM. This increase is the greater the larger the pressure drop and the smaller the clearances. Bearings also exert a major effect on the critical RPM of the rotor. This effect manifests itself in the so-called oil resonance (Laboratory of Hydraulic Machines AS UkSSR in cooperation with the Special Design Bureau of the Sum'skiy Pump Plant, under the direction of Corresponding Member of the AS UkSSR A. P. Filippov).

The compound oscillations of tandem systems were subjected to theoretical and experimental investigation in relation to the rotor parts of turbo-machines. The susceptibility of the disk to the frequency spectrum of tangential oscillations was found to exert a major influence. Studies were made of the dynamics of the transition through resonance as depending on the transition speed, which changed according to the exponential and power laws. A new method was established for determining the resonant amplitude (Laboratory of Hydraulic Machines AS UkSSR, under the direction of Corresponding Member of the AS UkSSR A. P. Filippov).

The frequency and shape of the oscillations of two-dimensional continuums (blades of hydraulic turbines) were determined on taking into account their angles of twist and curvatures and the effect of the ambient water as well. The effect of the nonrigid reinforcement of bracket plates was established. In particular, use was made of the methods

of modeling the oscillatory processes on materials with a low elasticity modulus (Laboratory of Hydraulic Machines AS UkSSR, under the direction of Corresponding Member of the AS UkSSR A. P. Filippov).

The compilation of programs for determining the critical rotor RPMs of turbo-machines by means of electronic computers proved to be very effective. These computers were used to compute the critical RPMs of the rotors of high-power 100,000-, 150,000- and 300,000-kilowatt steam turbines; in this connection the rotor was considered as a multiple supporting beam with staggered cross section and with "tochkovyye" /point? masses (Laboratory of Hydraulic Machines AS UkSSR, under the direction of Corresponding Member of the AS UkSSR A. P. Filippov).

The relationship between energy dissipation and the form of oscillations (torsional, longitudinal and flexural) was investigated. The effect of the scale factor and of the form of flexural oscillations on the decrease in damping was determined. Use was made of the methods of mathematical statistics for analyzing the process of energy dissipation in carbon steels. On the basis of a study of the damping of the oscillations of rod packets it was shown that basically energy dissipation takes place in the bonds (Institute of Powder Metallurgy and Special Alloys AS UkSSR, Kiev Polytechnical Institute, under the direction of Corresponding Member AS UkSSR G. S. Pisarenko).

6. In the Field of the Fatigue of Materials and Strength of Structures Under Variable Stresses. A statistical analysis of the stresses acting on the divided axles of automobiles; conducted according to characteristics developed in 1957, showed that such parts are characterized by a narrow spectrum of the frequencies of variable loads and therefore the calculation of strength can be limited to the consideration of the scope of the magnitudes of stresses.

The characteristics previously developed for analyzing the load and probable nature were used as the basis for designing optical-electronic apparatus which makes it possible to conduct statistical studies of stress margins in the presence of a negative correlation of extremal values.

Measurements of the chassis of the DT-54 tractor, and a statistical analysis of the results, showed that the variable load relating to the swiveling movements of the tractor, which load affects fundamentally the strength of the chassis, has a probable character and a narrow spectrum of the frequencies of extremal values, and is subject to the standard law of statistical distribution. These results made it possible to conduct a comparative appraisal of the

operational reliability of various design versions of the chassis of the DT-54 tractor and to outline the ways of improving its design.

An electromechanical model of an elastic system was used to reproduce the processes of probable loading, in which connection it was shown that the system is marked by the amplitude of a part of the spectrum of loadings which corresponds to the natural oscillation frequencies of the system.

The conduct of investigations of the fatigue of large and small cross-sectional specimens of perlitic-ferritic globular cast iron not subjected to thermal treatment made it possible to demonstrate the reduced sensitivity of that cast iron to the concentration of stresses; the decrease in the dissipation of disruptive strength and, in this connection, the smaller effect of absolute dimensions as well. Tests under scheduled loads showed that the fatigue damage sustained by this cast iron is expressed more feebly than that sustained by a similar cast iron when it is subjected to thermal treatment, although not to such an extent as in the cast iron with ferritic structure.

Observations of the growth of fatigue cracks made it possible to show that in its initial stages the rate of this growth is but little affected by stress, but in the stages close to ultimate disruption the crack develops the faster the greater the stress.

On the basis of these results it can be assumed that thermally untreated perlitic-ferritic cast iron is superior in strength to the thermally treated iron when used in dynamically stressed machine parts.

A mechanical system with two degrees of freedom was developed for a high-frequency testing machine whose use has made it possible to create resonant oscillations in specimens. A selection of parameters of the excitation system was made. It is planned to increase the frequency to 1,000 cps.

The continued analysis of oscillatory processes in the systems for testing variable bending made it possible to characterize the errors which take place when determining the stresses in the investigated machine part or metal specimen according to parameters of the system during operation at a set intensity or at a set displacement.

The role of dynamic parameters was analyzed and the stability and effectiveness of excitation were ensured in machines with a dynamic system of two degrees of freedom. The continued automation and perfecting of the machines used for scheduled fatigue tests made it possible to develop a

standard design of such machines, which was constructed for a number of organizations.

The crankshafts of the standardized automobile tractor type engines were subjected to natural fatigue tests which made it possible to determine the effect of structure, thermal treatment and technological defects on the fatigue of these crankshafts, and which served as a foundation for using cast-iron shafts in their mass production and for providing recommendations as to the problems of the technology of production of steel crankshafts.

All the results enumerated above in Point 6 were obtained at the Institute of Foundry Industry under the direction of Academician AS UkSSR S. V. Serensen.

Low-carbon steel was used as the material on which to study the negative role of hydration, which leads to a higher manifestation of brittleness during fatigue disruption, as well as to show the connection between the aggressiveness of the corrosive medium and the resistance to corrosive-fatigue disruption; this served as the basis for investigating the effect of surface hardening (Institute of Machine Science and Automation AS UkSSR, under the direction of Dr. Eng. Sci. G. V. Karpenko).

A study was made of the fatigue of two types of welded joints during pulsating and asymmetrical cycles for the 15GS, 14G2, 19G, and 14KhGS alloyed steels in connection with their use in metal structures (Institute of Electric Welding imeni E. O. Paton, under the guidance of Candidate of Eng. Sci. V. V. Shevernits'kyy).

Mass tests of the bending endurance of two powdered-metal-alloy silicon carbide compositions under normal and elevated (1,200 and 1,350°C) temperatures showed that the durability distribution is subject to the standard law, that the endurance limit at 1,350°C is virtually no smaller than the standard one at 1,200°C although the spread of the indexes of fatigue strength decreases with increasing temperature.

Studies of the bending endurance of carbide-chrome powdered-metal-alloy materials at the temperature of 900°C revealed that considerable plastic flowage occurs during a cyclical pulsating bending in these materials, which are very brittle in short-term tests (regardless of temperature). Upon applying a tensile stress to specimens of the powdered-metal-alloy materials subjected to the action of cyclical bending, considerable decreases in the endurance limits were revealed at a nearly symmetrical cycle in the zone of standard and elevated temperatures. Upon the application of a compressive stress the endurance limit rises considerably.

In the latter case, prolonged growth of the fatigue crack is observed, whereas in the other examined cases of fatigue of these too brittle materials no widening of cracks could be observed. It is recommended that these investigations of the fatigue of powdered-metal-alloy materials prepared mainly from silicon and chromium carbides be continued on the basis of 700,000-800,000 cycles, i. e., on a basis 100 to 10 times as small as that applied to cast materials (Institute of Powder Metallurgy and Special Alloys AS UkSSR, under the direction of Corresponding Member AS UkSSR G. S. Pisarenko).

Specimens of the EI 437 B alloy with and without stress concentrators [notches] were tested for fatigue at temperatures of 20 and 700°C on the basis of  $15-20 \cdot 10^7$  cycles, and so were specimens of EI 612 steel, at temperatures of 20, 500 and 600°C and on the basis of  $200-250 \cdot 10^6$  cycles, for the purpose of utilizing the results for the computation of turbine blades (Institute of Powder Metallurgy and Special Alloys AS UkSSR, under the direction of Corresponding Member AS UkSSR G. S. Pisarenko).

Also investigated was the effect of preliminary plastic tensile strain on the endurance characteristics of the EI 437B alloy (Institute of Structural Mechanics AS UkSSR, under the direction of Candidate Eng. Sci. M. I. Chernyak).

An installation was designed for investigating endurance under the conditions of elevated temperatures at ultrasonic frequencies (Institute of Powder Metallurgy and Special Alloys AS UkSSR, under the direction of Corresponding Member AS UkSSR G. S. Pisarenko).

It was established that under the influence of the rare-metal melts of Pb-Sn and Pb-Bi the fatigue of the specimens of low-carbon steels in the presence of concentrations of stresses, on the adopted basis of tests involving complete wetting, may increase by 30-50 percent compared with tests made in the air. At the same time, investigations of the unnotched specimens showed a strong relationship between fatigue in the rare-metal melts and the structural state of the steel. Installations were designed for investigating the endurance of materials at elevated temperatures in rare melts (Institute of Machine Science and Automation AS UkSSR, under the direction of Dr. Eng. Sci. G. V. Karpenko).

7. In the Field of Strength Under the Action of Dynamic Loads. Formulas were composed for determining the bending moments and shear stresses arising in gimbal-jointed rotating beams and rectangular plates under the action of instantaneous and uniformly distributed impacts (Institute of Structural Mechanics AS UkSSR, under the direction of

Dr. Eng. Sci. V. G. Chudnovskyy).

Research was continued in the dynamics of threads of varying length and in the dynamics of naturally twisted threads, and basic equations were derived for transverse torsional oscillations of flexible conductors; and the problems of the independence of load at a drastic change in the lifting force were investigated (Institute of Structural Mechanics AS UkSSR, under the direction of Academician AS UkSSR G. M. Savin).

As a result of the scientific research activity of the institutes of the Division of Engineering Sciences of the Academy of Sciences Ukrainian SSR in 1958 on the problem "The Scientific Bases of Strength and Plasticity," scientific-technical assistance was provided to industry, both by transmitting to enterprises information on the results of research in the form of engineering methods and data for computing the strength of compound mechanical systems, and by collaborating with the interested industrial organizations in executing the calculations of the strength of unique machines and structures.

As a result of the coordination of the labors on the problem "The Scientific Bases of Strength and Plasticity," the following conferences were convened in 1958 with the wide participation by scientists of the AS UkSSR, branch scientific research institutes, higher educational institutions, and engineers from the leading branches of industry.

1. Conference on the Problems of Strength Under Selected and Variable Loads and Under High Temperatures (convened by the Coordinating Commission on the Problem "The Scientific Bases of Strength and Plasticity").

2. Conference on the Problems of the Strength of Heat-Resistant Materials (convened by the Institute of Powder Metallurgy and Special Alloys AS UkSSR).

3. Traveling Session of the Institute of Structural Mechanics AS UkSSR in the city of Mikolayev Nikolayev at the Southern Turbine Plant, on the problems of the strength of gas turbines.

At these conferences, light was shed on the results of research in the corresponding aspects of the problem of strength and plasticity, and the program of research for the next few years was outlined as well.

The scientific seminars on mechanics (in Kiev) and on oscillations (in Khar'kov) have been working regularly and they have accomplished a great deal of work on the coordination and raising of the methodological level of scientific research on the problem of strength and plasticity which is being conducted in the Ukrainian SSR.

END

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